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An Investigation of Market Concentration and Financial Stability in Property–Liability Insurance Industry

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Abstract

The article investigates whether the market concentration is associated with an insurer's financial stability in the U.S. property–liability insurance industry over the period 1992–2010. We employ two-stage least squares techniques with instrumental variables to address likely endogeneity problems. The results show that higher market concentration is associated with lower financial stability of insurance firms, consistent with the "concentration-fragility" view. Our results indicate that firm-specific characteristics including firm size, underwriting leverage, organizational form, product and geographical diversification, along with the exposure to natural catastrophes and macroeconomic conditions are important determinants in ensuring a safe and sound insurance system. Robustness tests using various estimation methods and alternative measures of financial stability present consistent results.

Introduction

Over the past two decades, the U.S. property–liability insurance industry has experienced significant structural changes due to technological advancement and changes in regulatory environment. The relaxation of regulation has led to increasing convergence of the financial marketplace and the adoption of regulatory risk-based capital (RBC) standards in 1993 has put pressure on insurers to set capital requirements in accordance with the risk they are taking. The intense competition caused by technological progress and increased exposure to catastrophic risk provides insurance firm with incentives to seek improvements in cost and revenue efficiency by engaging in merger and acquisition (M&A) transactions (Cummins and Xie, 2008). There had been considerable M&A activities along with entry and exit in the property–liability insurance industry during the 1990s and many insurers have

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grown in size through M&As. Periods of structural change have posed both challenges and opportunities for insurers.

Although such a restructuring environment has substantially changed the market concentration of the U.S. property–liability insurance industry, limited attention is paid to the issue of whether changes in the market concentration owing to insurance firms being closed, absorbed into larger groups, or new entrants have a beneficial impact on the financial stability of the firms operating in an industry. The previous studies have typically focused on the effect of market structure on the firm performance in the insurance industry (e.g., Carroll, 1993; Chidambaran, Pugel, and Saunders, 1997; Bajtelsmit and Bouzouita, 1998; Choi and Weiss, 2005; Pope and Ma, 2008).[1] Despite its increasing importance, no prior studies in the insurance industry explicitly assess the effect of market concentration on the insurer's financial stability (our measure of financial stability is discussed later). This study attempts to fill the gap by providing new evidence on this issue.

The U.S. property–liability insurance industry is competitively structured in terms of the number of insurance firms as well as the products and services insurers offer. There are more than 2,500 affiliated and unaffiliated property–liability insurance companies that compete for business from millions of customers and corporations with diverse needs in the U.S. property–liability insurance industry. However, Bajtelsmit and Bouzouita (1998) argue that a large number of firms do not necessarily indicate that prices are competitive. In fact, insurance price regulation, such as prior approval law, is likely to affect competitive market forces to determine equilibrium prices and may discourage price competition. Although the U.S. property–liability insurance market has observed a large number of new entrants since the deregulation in the 1990s, the market concentration has been increasing over time, possibly due to a wave of M&A activities. For instance, the top 20 insurance groups and companies account for about 64 percent of the total U.S. property–liability insurance market share in 2010, whereas the top 20 insurance groups and companies maintained approximately 51 percent of the total market share in 1994.[2] The relationship between changes in market concentration and financial stability of insurers is an important question for policy-makers who develop policies about industry structure including M&A guidelines and market competitiveness. The empirical evidence on this issue can provide important implications for insurance regulators who are concerned

[1] In insurance studies of the structure–performance relationship, performance is measured in the form of prices and profits. Carroll (1993), Bajtelsmit and Bouzouita (1998), Choi and Weiss (2005), and Pope and Ma (2008) use a similar form of the underwriting profit margin as a proxy for insurer performance. Choi and Weiss also employ price estimated as premiums earned divided by the present value of losses incurred to measure insurer performance. Chidambaran, Pugel, and Saunders (1997) adopt the economic loss ratio as a measure of pricing performance. The use of the underwriting profit margin as a measure of profitability or performance may create a measurement problem and some distortions because it does not include investment income (Carroll, 1993). Note that insurers' profits (losses) primarily depend on the performance of both investment and underwriting activities.

[2] Market share of the top 20 insurers is the proportion of net premiums written held by the largest 20 insurance groups or companies.

about safety of insurers and seek to ensure the financial soundness of insurance market.

There have been two conflicting predictions about the relationship between market concentration and financial stability in the literature (e.g., Mishkin, 1999; De Nicoló, Bartholomew, Zaman, and Zephirin, 2004; Beck, Demirgüç-Kunt, and Levine, 2006; Uhde and Heimeshoff, 2009). The "concentration-stability" view asserts that a highly concentrated market system characterized by a few large firms is more stable than a less concentrated system with many small firms. Large firms operating in highly concentrated markets are likely to earn more profits through the implementation of market power. Firms with better profit opportunities have the ability to increase more capital, and thus the probability of firm failure in concentrated markets is likely to be lower.

On the other hand, the "concentration-fragility" view argues that a more concentrated market structure with a few large firms is more susceptible to financial fragility than a less concentrated market system. According to the so-called phenomenon of "too big to fail," large financial institutions should be supported by government when they face financial difficulty because the failure of large financial institutions could result in severe consequences in all financial markets and the economy due to the contagion effect. Thus, large financial institutions in the concentrated market system are likely to receive a government subsidy when needed. This protective policy may create moral hazard problems such as increasing the firm's risk-taking incentives (Mishkin, 1999). The resulting moral hazard and risk taking, in turn, may lead to financial instability (Gan, 2004). The prediction about firm behavior under the concentration-fragility view applies well to the example of American International Group (AIG) collapse during the recent financial crisis. Note that AIG triggered the massive bailout by the U.S. government due to the liquidity problem, which resulted from its excessive noninsurance activities in speculative derivatives markets.

Several banking studies have investigated whether the concentration-stability view or the concentration-fragility view holds. However, the results are not conclusive. For example, Gan (2004) and Beck, Demirgüç-Kunt, and Levine (2006) show that a concentrated market structure is positively related to financial stability. Their results provide evidence that confirms concentration-stability view. De Nicoló, Bartholomew, Zaman, and Zephirin (2004) and Uhde and Heimeshoff (2009) find a negative impact of market concentration on the firm's financial soundness, which supports the concentration-fragility view. The inconsistent empirical results and the countervailing predictions provide the motivation for further empirical examination. Because no previous studies in the insurance industry examine these two competing hypotheses, we aim to shed light on whether market concentration is positively (negatively) associated with financial stability using the sample of the U.S. property–liability insurance industry.

We initially focus on company-wide analysis to examine how national-level market concentration affects an individual insurance firm's financial stability. In our primary specification, company-level financial stability is measured using the Z-score, which is commonly employed as a proxy measure of the likelihood of insolvency in the literature (e.g., Stiroh and Rumble, 2006; Laeven and Levine, 2009; Uhde and Heimeshoff, 2009; Shim, 2011). As prior banking studies of market structure use

company-level performance data, one advantage of using company-level data instead of line-level data is to purge the impact of any cross-subsidization across lines of business (Choi and Weiss, 2005). It would be also true that competition occurs locally and that market concentration and regulation change by state. Thus, we additionally perform a state-wide analysis by measuring market concentration and financial stability by company and state. The standard deviations of the state-wide loss ratio and combined ratio are used to measure an insurer's financial stability in the state-wide sample analysis. An analysis using the *Z*-score and standard deviations of loss and combined ratios at the company and state levels as dependent variables provides a more complete picture for the relationship between market concentration and financial stability.

We employ two-stage least squares (2SLS) estimation techniques using instrumental variables to address likely endogeneity problems. By way of preview, we find that increasing market concentration has a negative impact on the firm's financial stability, consistent with the concentration-fragility view. We examine a variety of firm characteristics that may affect the insurer's financial stability. We show that the form of mutual insurers, product, and geographical diversification have a positive effect on the insurer's financial stability, while underwriting leverage, reinsurance, and the decrease in interest rate have a negative impact on the insurer's financial stability. Notably, it appears that the relationships between firm size and an insurer's insolvency risk are nonlinear. We also provide evidence that severe damages from natural catastrophes have a significant negative impact on the insurer's financial health.

The article is structured as follows. The "Literature Review" section reviews the literature about the relationship between market concentration and financial stability. Hypotheses and variables estimation are discussed in the "Hypotheses and Variable Estimation" section. The "Data Description" section describes data and sample selection. The regression specification, empirical results and robustness tests are presented in the "Methodology and Empirical Results" section. The "Conclusion" section concludes with a summary of the main findings.

LITERATURE REVIEW

The extant insurance literature has focused on examining the effect of market concentration on firm performance. Bajtelsmit and Bouzouita (1998) provide evidence that market concentration by state has a significantly positive impact on profitability in the private passenger automobile insurance over the period 1984–1992. Chidambaran, Pugel, and Saunders (1997) suggest that the concentration ratio for the line is one significant determinant of pricing performance. They find that the line's concentration ratio is negatively related to the economic loss ratio in the U.S. property–liability insurance industry. Carroll (1993) finds no significant relationship between concentration and profitability in the U.S. workers' compensation market for the period 1980–1987. Choi and Weiss (2005) investigate the relationship that exists between market structure and performance in U.S. property–liability insurers for the period 1992–1998. Their results suggest that cost-efficient insurers gain larger market shares by charging lower prices and earn higher profits, leading to increased concentration. Pope and Ma (2008) address the potential impact of market structure on performance in the international nonlife insurance market over the period 1996–

2003. Their results show that concentration is positively related to profitability when a country has a low level of liberalization. However, the relationship is reversed when the level of liberalization is high.

Because the relationship between the market concentration and financial stability has been long discussed in the banking sector, we turn our attention to the banking literature. Despite extensive research, there is little consensus on how market concentration is associated with the bank's financial soundness. The present theoretical and empirical studies provide countervailing predictions and contradictory evidence about the effect of market concentration on financial stability.

The concentration-stability view argues the advantage of market concentration, suggesting that more market concentration is associated with higher financial stability. Allen and Gale (2000, 2004) assert that a concentrated banking sector with a few banks is less susceptible to financial crises than a less concentrated banking sector with many banks. Montgomery (1985) argues that firms operating in highly concentrated markets are more likely to benefit from higher prices and higher profitability. Banks in more concentrated markets may create profits through the exercise of market power in charging prices. Banks with high profits facilitate building up a capital buffer to provide protection against adverse financial shocks, and thus the probability of financial distress gets lower. Boyd, De Nicoló, and Smith (2004) find that large (monopolistic) banks in a more concentrated banking system have a lower likelihood of a banking crisis due to higher capital buffers that protect them against external macroeconomic and liquidity shocks. Boyd and Prescott (1986) also state that concentrated market increases financial stability in banking system because larger banks are able to diversify loan portfolio risks more efficiently and achieve economies of scale and scope. Beck, Demirgüç-Kunt, and Levine (2006) show that more concentrated banking systems tend to reduce the likelihood of a systemic banking crisis. Some proponents of the concentration-stability view suggest that a higher charter or franchise value reduces bank owners' and managers' incentives to take excessive risks since the costs associated with bank failure are severe (Keeley, 1990; Park and Peristiani, 2007).

In contrast, the concentration-fragility view predicts a negative relationship between market concentration and financial stability. The theoretical and empirical literature supporting this view indicates that a concentrated banking structure characterized by fewer banks enhances bank fragility. Large banks in concentrated banking systems tend to receive a greater net subsidy from the government through implicit "too big to fail" policies. This subsidy may increase the risk-taking incentives of the larger banks and hence enhances banking system fragility (Mishkin, 1999). The moral hazard problem becomes more severe for larger banks where managers may take on riskier investments under a government safety net. Uhde and Heimeshoff (2009) show that increasing market concentration has a negative impact on European banks' financial soundness. De Nicoló, Bartholomew, Zaman, and Zephirin (2004) report that more concentrated banking systems exhibit higher levels of systemic risk potential than less concentrated banking systems do. Chong (1991) finds that bank consolidation is likely to increase the riskiness of banking system. Caminal and Matutes (2002) show that less competition may result in a higher probability of bank failures.

HYPOTHESES AND VARIABLE ESTIMATION

The main objective of this study is to investigate the relationship between market concentration and financial stability in the U.S. property–liability insurance industry. Financial stability requires firms to endure fundamental shocks such as depletion of capital due to large catastrophes, unanticipated interest rate changes, or adverse asset returns without collapsing. In this article, financial stability is measured by using the *Z*-score, which has been widely used in the literature as a proxy measure of the likelihood of firm insolvency (Eisenbeis and Kwast, 1991; Sinkey and Nash, 1993; Stiroh and Rumble, 2006; Demirguc-Kunt, Detragiache, and Tressel, 2008; Laeven and Levine, 2009; Shim, 2011). The *Z*-score measures the number of standard deviations by which returns should fall to wipe out all of the insurer's equity capital. More specifically, the *Z*-score is measured as[3]

$$Z\text{-score} = \frac{\text{ROA} + \text{Capital to Asset Ratio}}{\text{Standard Deviation of ROA}}, \tag{1}$$

where ROA is the return on asset calculated by net income after policyholder dividend but before taxes divided by total assets. The standard deviation of ROA is calculated by using 5-year rolling periods data. For example, the standard deviation of ROA for 1996 is calculated using the ROA over the 5-year observations between 1992 and 1996. The volatility of profits (or ROA) is costly if large variations in earnings increase the probability of default and insurers are forced to raise external capital to ensure their solvency. The *Z*-score increases as an insurer' profitability and capital ratio improve, and the *Z*-score decreases with increasing volatility of asset returns. In fact, the *Z*-score is inversely related to the probability of insolvency, with higher *Z*-score indicating a lower probability of default. Therefore, a higher (lower) *Z*-score implies higher (lower) financial stability.

Market Concentration

Market concentration is the key explanatory variable in this study. Consistent with many industrial organization studies, an industry Herfindahl index (HHI) is used to measure market concentration. The industry HHI is calculated by the sum of the squares of the percentages of net premium written (NPW) across all firms ($i = 1$ to n) operating in the U.S. property–liability insurance industry for each year t.

$$\text{HHI}_t = \sum_{i=1}^{n} \left[\frac{\text{NPW}_{i,t}}{\sum_{i=1}^{n} \text{NPW}_{i,t}} \right]^2. \tag{2}$$

A high industry HHI indicates a concentrated market where a few large companies dominate the market, whereas a low industry HHI suggests a less concentrated market in which the market is spread among many companies, each with only a small

[3] Capital refers to policyholders' surplus in the *Z*-score formula.

share of the market. As alternative measures of market concentration, we also use the 4-, 8-, and 20-firm concentration ratios (C4, C8, and C20) measured by the proportion of NPWs held by the largest 4, 8, and 20 insurers, respectively, in each year. A high concentration ratio denotes a more concentrated market since the market is controlled by a few large firms. The concentration ratios are widely employed to represent market competition in the literature (e.g., Chidambaran, Pugel, and Saunders, 1997; Bajtelsmit and Bouzouita, 1998; Pope and Ma, 2008). Similar to Cummins, Tennyson, and Weiss (1999), the industry HHI and firm concentration ratios are also measured using the insurer's assets. Based on the discussion of two competing views in the "Literature Review" section, we predict that the insurer's market concentration is positively associated with financial stability if the concentration-stability view holds. On the other hand, we expect a negative relationship between market concentration and the insurer's financial stability if the concentration-fragility view is valid for our given data.

Firm Size

The expected impact of firm size on financial stability is ambiguous *a priori*. Cummins, Harrington, and Klein (1995) assert that small insurers are more likely to be vulnerable to insolvency because regulators are less likely to liquidate large insurers than small insurers. Adam and Buckle (2003) argue that large insurers are able to effectively diversify their assumed risks and respond more quickly to changes in market conditions. On the contrary, Lai and Limpaphayom (2003) show an inverse relationship between firm size and profitability in the Japanese nonlife insurance industry. Shim (2011) finds that acquirers' overall financial performance decreases and volatility of earnings increases during the gestation period following M&As, implying that firm size may be inversely related to financial stability. These divergent results indicate that the expected relationship remains unclear. The natural logarithm of total assets is used as a proxy for firm size. We also include the square of firm size to explore possible nonlinear relationships between firm size and its insolvency risk.[4]

Catastrophes

Catastrophic losses caused by natural disasters are likely to pose severe problems for insurers operating in catastrophe-prone lines of business. To address the impact of catastrophic losses on the insurer's financial stability, we include a variable that captures the exposure to catastrophes in our regression analysis. Similar to Born and Klimaszewski-Blettner (2013), exposure to catastrophes is measured as nation-wide sum of property damages from natural catastrophes divided by the sum of all insurers' direct premiums written in fire, allied, commercial multiple peril, and homeowners lines. We expect this variable to be negatively related to the insurer's

[4] We may face a potential collinearity problem if firm size and its quadratic term are highly correlated. The centering method where we subtract the mean of the firm size from individual observations is used to circumvent this problem (e.g., Hocking, 2003). By centering the data, we have substantially reduced the correlation between firm size and the square of firm size.

financial strength because large unexpected property losses due to an increase in natural catastrophes may destabilize the insurer's underwriting performance.

Leverage

Underwriting leverage is measured as NPW relative to policyholders' surplus.[5] An insurer's leverage ratio is limited by regulatory guidelines and inversely related to the insurer's underwriting capacity to write additional business. An insurer should have adequate policyholders' surplus if it intends to increase its written premium volume. A firm having relatively lower levels of surplus is more likely to become insolvent than a firm with higher levels of surplus. Carson and Hoyt (1995) find that insurers with a low ratio of premium written to surplus have a lower probability of insolvency. We predict that underwriting leverage is negatively related to financial stability.

Product Diversification

Product diversification is measured using the HHI (ProdHHI). ProdHHI is calculated as the sum of the squares of the percentages of direct premium written across product lines.[6] Lower HHI indicates higher diversification. Hoyt and Trieschmann (1991) find that diversified insurers have lower mean returns and higher total variation relative to particular segment of life–health and property–liability insurers. Cummins and Nini (2002) find that diversification is negatively related to return on equity. However, Meador, Ryan, and Schellhorn (2000) find that diversified firms are more X-efficient than focused firms because diversified insurers can achieve greater cost efficiency by sharing inputs across multiple product lines and allocating resources efficiently in response to changing industry conditions. Thus, the expected sign of ProdHHI may *a priori* be ambiguous.

Geographic Diversification

Geographical diversity is also included to investigate whether geographical diversification improves financial stability. Geographical HHI (GeoHHI) is measured as the sum of the squares of the percentages of direct premium written across 50 states for each insurer. GeoHHI is predicted to have a negative sign if diversifying across geographic areas reduces underwriting risk. In contrast, it may have a positive sign if geographically diversified insurers have lower returns and higher total variation relative to geographically focused insurers.

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[5] Policyholders' surplus is the difference between an insurer's assets and its liabilities, and it represents the firm's net worth. Surplus (capital) serves as the financial cushion that insurance companies use to absorb unexpected losses.

[6] The product lines included in the calculation of HHI are approximately 30 different lines of business. We consider the entire number of product lines presented by the National Association of Insurance Commissioners' (NAIC) annual statutory filings. These numbers slightly change in any given year. Alternatively, we use 24 lines by consolidating some of product lines similar to the literature (e.g., Berry-Stolzle, Liebenberg, Ruhland, and Sommer, 2012). The results are not changed.

Homeowners Line Share

The percentage of direct premium written in homeowners line is included to examine the relationship between the variation in specific product line proportion and the financial strength of insurers. Homeowner risks are often highly dependent, and high accumulation risk adversely influences insurers' performance if insurers are not sufficiently diversified (Born and Viscusi, 2006). Born and Klimaszewski-Blettner (2013) suggest that homeowner insurers have a particularly difficult time providing stable coverage in the wake of severe damages from catastrophic events. We expect that insurers with more homeowners (HO) line shares experience financial instability if homeowners lines are particularly vulnerable to catastrophic risks and more volatile than other personal and commercial lines.

Invest in Bonds

We include the percentage of the investment portfolio invested in bonds to control for the riskiness of a particular investment. An insurer's asset portfolio combination affects not only the scale but also the variability of its returns (Elango, Ma, and Pope, 2008). Investments in risky assets may generate higher returns. However, they may also produce greater volatility in such returns. Browne, Carson, and Hoyt (2001) document that stocks, real estate, and mortgages are relatively more risky investments. We expect a positive effect of investment in bonds on the insurer's financial stability because the higher the percentage of an insurer's investment in safer assets, the lower the insolvency risk an insurer will face due to less volatility of investment returns.

Reinsurance Ratio

Reinsurance is used to provide financial protection to the ceding company against a catastrophic loss. The purchase of reinsurance can increase the primary insurer's underwriting capacity to write new business and allow an insurer to hold less capital without increasing the probability of its insolvency. Similar to Cole and McCullough (2006), reinsurance ratio is measured as reinsurance ceded to nonaffiliates divided by the sum of direct premiums written and reinsurance assumed from nonaffiliates. We expect the reinsurance ratio to be positively associated with the insurer's financial stability.

Asset Growth

The firm-specific variables include the asset growth rates. Asset growth is measured as the percentage change in total assets of each insurer in each year, defined as $(\text{Asset}_{i,t} - \text{Asset}_{i,t-1})/\text{Asset}_{i,t-1}$. The impact of asset growth on the financial stability of insurers is expected to be negative if rapid asset growth results from an increase in the proportion of certain risky assets in an insurer's asset portfolio.

Mutual

We control for organizational form by including an indicator variable equal to one for mutual firms, and zero otherwise. Lee, Mayers, and Smith (1997) argue that incentives to increase asset risk are better controlled in mutuals than in stocks because in a mutual, the incentive conflict is controlled by merging ownership claims with

policyholders' claims. Managers of stock insurers have more incentives to increase asset risk because of compensation packages such as stock options. Ho, Lai, and Lee (2013) find that mutual insurers have lower total, underwriting, and investment risks than stock insurers. We expect this variable to be positively related to the insurer's financial stability because mutual insurers are less likely to take excessive risks compared to stock companies.

Group

An indicator variable equal to one for groups and zero for unaffiliated insurers is included to control for variation in an insurer's financial strength by different firm structures. It is common for insurers to be affiliates of an insurance group, and capital transfers are active within groups of insurance companies. Affiliated insurers are more likely to endure financial shocks because they can exchange capital by assuming and ceding reinsurance, predicting this variable will be positively associated with the insurer's financial stability.

Interest Rate Change

As the economic environment changes, insurance companies face considerable challenges that may pose a major threat to performance and financial stability. The changes of interest rates have many implications for the insurer's earnings, premium rates, and product designs. The most noticeable impact is on the book yields of their account portfolios, and interest earnings are a significant source of revenue for insurers. Insurers are more likely to be financially unstable if low interest rates represent a substantial reduction in investment income. We use the changes in the federal funds rate to examine its impact on the insurer's financial stability. The interest rate changes are predicted to be positively related to the insurer's financial strength.

DATA DESCRIPTION

For our empirical analyses, we employ accounting data of the U.S. property–liability insurance industry from the regulatory annual statements filed to the NAIC for the years 1992–2010.[7] The interest rate is obtained from the Federal Reserve System. We obtain catastrophic loss data from SHELDUS^{TM}, which is a county- and state-level hazard loss data set for the U.S. territories for 18 different types of natural hazard events including hurricanes, floods, wild fires, tornados, and thunderstorms. SHELDUS^{TM} include events that created more than $50,000 in damages or at least one death.

Our initial data include all U.S. property–liability insurance firms that report their financial statements to the NAIC. Because insurers compete with each other at the group and unaffiliated single company levels, it is more appropriate to measure

[7] As a result of calculating the standard deviation of ROA, standard deviation of statewide loss ratio, and combined ratio by using 5-year rolling periods, data for regression analysis span the period from 1996 through 2010.

market share proportions and concentration ratios by decision-making unit, that is, for groups and unaffiliated single companies. Thus, affiliated firms operated under common ownership and management are consolidated as one observation unit. In this case, affiliated firm-level data are aggregated to the group level and the values for indicator variables are determined on the basis of the lead insurer in the group. The leader of the group is selected based on total assets.

Similar to the literature, we exclude firms that report unusual financial ratios and/or nonpositive values for assets, premiums written/earned, or policyholders' surplus. We omit insurers that do not report their financial statements for at least 5 years. Also eliminated from the sample are reinsurers and insurers that were put into liquidation during the sample period. The resulting sample used in the primary specification (state-level analysis) is an unbalanced panel and consists of 14,017 (160,134) firm-year observations. Table 1 reports descriptive statistics on the variables of financial stability, market concentration, and firm-specific factors at both the company and state levels.

METHODOLOGY AND EMPIRICAL RESULTS

Primary Specification

To examine the relationship between market concentration and financial stability while controlling for firm-specific and macroeconomic characteristics, we conduct regression analyses using a series of pooled, cross-sectional, and time-series data. Regressions are estimated initially using ordinary least squares (OLS) with clustering at the firm level. We estimate White's (1980) standard errors, which are robust to within-cluster correlation (Petersen, 2009). To test our hypotheses, the basic regression specification using company-level data can be written as follows:[8]

$$\begin{aligned}\ln(Z\text{-score}_{i,t}) = {} & \beta_0 + \beta_1 \text{Concentration}_t + \beta_2 \text{FirmSize}_{i,t} + \beta_3 \text{FirmSize}^2_{i,t} \\ & + \beta_4 \text{Catastrophes}_t + \beta_5 \text{Leverage}_{i,t} + \beta_6 \text{ProdHHI}_{i,t} \\ & + \beta_7 \text{GeoHHI}_{i,t} + \beta_8 \text{HOLineShare}_{i,t} + \beta_9 \text{InvestinBonds}_{i,t} \\ & + \beta_{10} \text{Reinsurance}_{i,t} + \beta_{11} \text{AssetGrowth}_{i,t} + \beta_{12} \text{Mutual}_{i,t} \\ & + \beta_{13} \text{Group}_{i,t} + \beta_{14} \text{Interest}_t + \varepsilon_{i,t}, \end{aligned} \tag{3}$$

where i indexes the group or unaffiliated company, t represents time, and $\varepsilon_{i,t}$ is the error term. Given the skewness of the Z-score across our sample firms, we define our dependent variable as the natural logarithm of the Z-score.[9] Laeven and Levine (2009) use the natural logarithm of the Z-score to measure bank risk in their empirical assessment of whether the impact of bank regulations on bank risk depends on each bank's ownership structure. Our primary interest in the analysis is the concentration

[8] Time dummies are omitted because of collinearity with our key independent variable, market concentration. Note that market concentration ratios vary by year, but are invariant across firms at a given specific period of time (a year).

[9] We run regressions without taking the natural logarithm for the Z-score and find that the key results are unaffected. The results are not reported to preserve space, but are available upon request.

TABLE 1
Summary Statistics for Variables Used in Regressions, 1992–2010

Variable	Mean	Median	Std Dev	Minimum	Maximum
Company level					
Z-score	20.2248	14.4613	17.9899	0.0057	99.9575
Opportunity asset risk	0.0414	0.0361	0.0244	0.0015	0.5843
A.M. Best's ratings	0.2343	0.0000	0.4237	0.0000	1.0000
Concentration (NPW_HHI)	0.0328	0.0335	0.0018	0.0295	0.0349
Concentration (NPW_C4)	0.2819	0.2834	0.0095	0.2600	0.2946
Concentration (NPW_C8)	0.4250	0.4347	0.0289	0.3706	0.4626
Concentration (NPW_C20)	0.6148	0.6265	0.0295	0.5426	0.6430
Concentration (Asset_HHI)	0.0318	0.0324	0.0028	0.0257	0.0363
Concentration (Asset_C4)	0.2886	0.2919	0.0202	0.2468	0.3156
Concentration (Asset_C8)	0.4293	0.4317	0.0213	0.3769	0.4531
Concentration (Asset_C20)	0.6280	0.6355	0.0197	0.5699	0.6454
FirmSize	10.8435	10.6254	2.1902	4.3781	18.5308
Catastrophes	0.1555	0.1301	0.1956	0.0424	0.8407
Leverage	1.0259	0.8507	0.9012	0.0000	14.8031
ProdHHI	0.5723	0.5064	0.3103	0.0753	1.0000
GeoHHI	0.6450	0.8171	0.3806	0.0347	1.0000
HOLineShare	0.1150	0.0000	0.2049	0.0000	1.0000
InvestinBonds	0.5983	0.6738	0.2717	0.0000	0.9997
Reinsurance	0.2248	0.1592	0.2200	0.0000	0.9989
AssetGrowth	0.0853	0.0602	0.2536	−0.9723	4.7377
Mutual	0.3486	0.0000	0.4766	0.0000	1.0000
Group	0.3799	0.0000	0.4854	0.0000	1.0000
Interest	−0.0432	−0.0201	0.5288	−0.9167	1.3852
PremiumGrowth	0.1008	0.0411	0.5139	−7.3575	9.6476
GDPGrowth	0.0237	0.0303	0.0217	−0.0349	0.0483
State level					
SD_LR	0.4575	0.2624	0.6003	0.0000	5.2227
SD_CR	0.4948	0.2973	0.6137	0.0000	4.8563
St.Concentration (HHI)	0.0475	0.0459	0.0095	0.0281	0.1043
St.Concentration (C4)	0.3460	0.3437	0.0489	0.2304	0.5502
St.Concentration (C8)	0.5128	0.5139	0.0492	0.3687	0.6815
St.Concentration (C20)	0.7415	0.7374	0.0411	0.6022	0.8595
St.FirmSize	3.1815	3.2310	1.3399	0.0000	9.5200
St.Catastrophes	0.1828	0.0275	1.3387	0.0000	28.7126
St.HOLineShare	0.0445	0.0000	0.1305	0.0000	1.0000
Regulation	0.4915	0.0000	0.4999	0.0000	1.0000
St.PremiumGrowth	0.1831	0.0221	1.0186	−9.9167	9.9991
St.GDPGrowth	0.0402	0.0256	0.0519	−0.0489	0.2245

Note: This table presents descriptive statistics for the variables used in the regression. The sample used in the primary specification (state-level analysis) consists of 14,017 (160,134) firm-year observations for the years 1992–2010. The *Z*-score is measured by the return on assets (ROA) plus the capital-to-asset ratio divided by the standard deviation of ROA. Opportunity asset risk is defined as the annualized standard deviation of the weighted average returns of an insurer's invested asset portfolio. A.M. Best's ratings are the indicator equal to one for firms with A.M. Best's ratings of A++

or A+, and zero otherwise. Concentration (NPW_HHI) is calculated by the sum of the squares of the percentages of net premium written (NPW) across all firms operating in the U.S. property–liability insurance industry. Concentration (NPW_C4, NPW_C8, and NPW_C20) are the firm concentration ratios measured by the proportion of net premiums written held by the largest four (C4), eight (C8), and 20 (C20) insurers, respectively. Concentration (Asset_HHI, Asset_C4, Asset_C8, and Asset_C20) are measured by total assets. FirmSize is measured by the natural logarithm of total assets. Catastrophes are measured as nation-wide sum of property damages from natural catastrophes divided by the sum of all insurers' direct premiums written in fire, allied, commercial multiple peril, and homeowners lines. Leverage is measured as NPW relative to policyholders' surplus. ProdHHI is the product diversification measured by Herfindahl index across product lines. GeoHHI is the geographical diversification measured by Herfindahl index across 50 states. HOLineShare is the percentage of direct premium written in homeowners lines. InvestinBonds is the percentage of the investment portfolio invested in bonds. Reinsurance is the reinsurance ratio measured as reinsurance ceded to nonaffiliates divided by the sum of direct premiums written and reinsurance assumed from nonaffiliates. AssetGrowth is the annual percentage change in total assets. Mutual is the indicator variable equal to one for mutual firms, and zero otherwise. Group is the indicator variable equal to one for groups, and zero otherwise. Interest is the interest rate changes in the federal funds rate. PremiumGrowth is the 5-year average growth rate of an insurer's total NPW. GDPGrowth is the 3-year average growth rate of national real GDP. SD_LR is the standard deviation of state-wide loss ratio over past 5 years. SD_CR is the standard deviation of statewide combined ratio over past 5 years. St.Concentration (HHI) is the Herfindahl concentration index by state. St.Concentration (C4, C8, and C20) are the proportion of direct premiums written (DPW) held by the largest 4, 8, and 20 insurers, respectively, in each state. St.FirmSize is measured by the natural logarithm of DPW of each insurer in each state. St.Catastrophes are calculated by the state-wide sum of property damages from natural catastrophes divided by the sum of all insurers' direct premiums written in fire, allied, commercial multiple peril, and homeowners lines in that state. St.HOLineShare is the percentage of DPW in homeowners lines for each insurer in each state. Regulation is the indicator variable equal to one if the state is rate regulated, and zero otherwise. St.PremiumGrowth is the 5-year average growth rate of an insurer's state-level DPW. St.GDPGrowth is the 3-year average growth rate of state-level real GDP.

coefficient estimate. A positive coefficient would support the concentration-stability view, while a negative coefficient would provide evidence that supports the concentration-fragility view. The definitions and expected signs of the variables in Equation (3) are presented in Table 2.

The literature suggests that market concentration may be jointly determined with the firm's financial soundness, and the feedback effect between these independent and dependent variables may lead to the problem of endogeneity (e.g, Bajtelsmit and Bouzouita, 1998; Uhde and Heimeshoff, 2009). If the market concentration variable is not exogenous, the OLS estimation would be biased and inconsistent. Thus, we perform 2SLS methods using instrumental variables to deal with endogeneity problems.

We first conduct regression-based Hausman tests to address the potential endogeneity issue of market concentration variables. The Hausman tests can be performed in two stages (Wooldridge, 2002). The first stage is to regress market concentration on instrumental variables and all other explanatory variables listed in Equation (3). In the second stage, we include the residuals from the first-stage regression as an additional regressor in a regression of basic specification (Equation(3)). If the coefficient on the residual is statistically different from zero, we reject the null hypothesis of exogeneity.

TABLE 2
Variable Definitions and Expected Signs

Variable	Definition	Expected Sign
Company level		
Z-score	Sum of the returns on assets (ROA) and capital-to-asset ratio divided by standard deviation of ROA	
Opportunity asset risk	Ln(Annualized standard deviation of the weighted average returns of an insurer's invested asset portfolio)	
A.M. Best's ratings	Indicator equal to one for firms with A.M. Best's ratings of A++ or A+, and zero otherwise	
Concentration (HHI)	Market concentration, as measured by Herfindal index	±
Concentration (C4, C8, and C20)	Firm concentration ratio, as measured by the proportion of net premium written (assets) held by the largest four, eight and 20 insurers	±
FirmSize	Natural logarithm of total assets	±
Catastrophes	Nation-wide sum of property damages from natural catastrophes divided by the sum of all insurers' direct premiums written in fire, allied, commercial multiple peril, and homeowners lines	−
Leverage	Net premium written/Policyholders surplus	−
ProdHHI	Product diversification measured by Herfindal index across product lines	±
GeoHHI	Geographic Diversification measured by Herfindal index across 50 states	±
HOLineShare	Percentage of direct premium written in homeowners lines	−
InvestinBonds	Percentage of the investment portfolio invested in bonds	+
Reinsurance	Reinsurance ceded to nonaffiliates divided by the sum of direct premiums written and reinsurance assumed from nonaffiliates	+
AssetGrowth	Annual percentage change in total assets	−
Mutual	Indicator variable equal to one for mutual firms, and zero otherwise	+
Group	Indicator variable equal to one for groups, and zero otherwise	+
Interest	Interest rate changes in the federal funds rate	+
PremiumGrowth	5-year average growth rate of an insurer's total net premium written	
GDPGrowth	3-year average growth rate of national real GDP	

(*Continued*)

TABLE 2
Continued

Variable	Definition	Expected Sign
State level		
SD_LR	Standard deviation of statewide loss ratio over past 5 years	
SD_CR	Standard deviation of statewide combined ratio over past 5 years	
St.Concentration (HHI)	Herfindahl concentration index by state	±
St.Concentration (C4, C8, and C20)	Proportion of direct premiums written (DPW) held by the largest four, eight, and 20 insurers in each state	±
St.FirmSize	Natural logarithm of DPW of each insurer in each state	±
St.Catastrophes	State-wide sum of property damages from natural catastrophes divided by the sum of all insurers' direct premiums written in fire, allied, commercial multiple peril, and homeowners lines in that state	+
St.HOLineShare	Percentage of DPW in homeowners lines for each insurer in each state	+
Regulation	Indicator variable equal to one if the state is rate regulated, and zero otherwise	−
St.PremiumGrowth	5-year average growth rate of an insurer's state-level DPW	
St.GDPGrowth	3-year average growth rate of state-level real GDP	

Notes: PremiumGrowth (St.PremiumGrowth) and GDPGrowth (St.GDPGrowth) are instrumental variables used in the 2SLS method. For brevity, St. is used to indicate the state-level measurement.

Effective instrumental variables should satisfy two conditions (Wooldridge, 2002). The instrumental variables must be correlated with the endogenous explanatory variable, and they must be uncorrelated with the error term in the structural equation. The lagged or historically averaged measures of firm characteristics, industry growth, and general economic growth are suggested as commonly used instrumental variables (Campa and Kedia, 2002). The instrumental variables used for market concentration variables initially include average firm size for the prior 5 years, 5-year average growth rate of insurers' net premium written, firm age, 1-year growth rate in total admitted assets for the property–liability insurance industry, the number of M&A transactions in the property–liability insurance industry, 3-year average growth rate of real GDP, and lagged values of firm characteristics included in Equation (3).

We perform several tests to determine whether instrumental variables fulfill the two conditions discussed above. The partial R^2 and the F-test are used in the first stage to

assess the relevance of the excluded instruments.[10] The partial R^2 statistic gauges the degree of correlation between the endogenous variable and the excluded instruments after partialing out the effect of the included exogenous variables. The *F*-statistic measures the joint significance of the excluded instruments. If the *F*-statistic is significant, we reject the null hypothesis that the set of instruments is weak.[11] We examine whether the instruments are uncorrelated with the error term using Hansen's *J*-test of overidentifying restrictions. If the test statistic is significant, we reject the null hypothesis of valid instruments. The test results show that only 5-year average growth rate of insurers' net premium written and 3-year average growth rate of real GDP among the initially selected instrumental variable entrants satisfy both the relevance and validity requirements.

The estimated results of the Equation (3) using both OLS and 2SLS with instrumental variables are presented in Table 3. Columns 1–4 provide regression results using market concentration measured by NPW, and columns 5–8 provide results applying assets to estimate market concentration. Standard errors in parentheses are adjusted for heteroskedasticity and firm-level clustering (Petersen, 2009). We perform separate regressions for the robustness of our results by employing the 4-, 8-, and 20-firm concentration ratios (C4, C8, and C20) as alternative measures of market concentration.[12] The results of Hausman tests in columns 3, 4, 7, and 8 of Table 3 show that market concentration variables should be treated as endogenous because test statistics for all concentration variables are significant at the 5 percent level.[13] We report the partial R^2 of excluded instruments, the *p*-value of the *F*-test of excluded instruments, and the *p*-value of the overidentification test of excluded instruments. The partial R^2 statistic of excluded instruments shows that two instruments have significant explanatory power for the variation of market concentration variables after controlling for the effect of the included exogenous variables. The *p*-value of the *F*-test of excluded instruments is significant at the 1 percent level, indicating that our instruments are not weak.[14] Furthermore, we do not reject the null hypothesis that the instruments are uncorrelated with the error term because the *p*-values of the overidentification test (Hansen's *J*-test) range between 0.26 and 0.28 in all of the specifications. Thus, our instruments are valid.

[10] Laeven and Levine (2009) use the partial R^2 and the *F*-test to assess the relevance of the excluded instruments.

[11] The weak instruments may cause the 2SLS estimators to be biased, and inference based on the 2SLS estimator can be severely misleading (Stock, Wright, and Yogo, 2002).

[12] The results with 8- and 20-firm concentration ratios (C8 and C20) are available from the authors upon request.

[13] The Durbin–Wu–Hausman (DWH) tests are also conducted to examine whether we could treat market concentration variables as exogenous. The null hypothesis under the DWH tests is that the variable in question is exogenous. Because test statistics are highly significant, we reject the null hypothesis of exogeneity.

[14] The Wald test attains the same conclusion that our instruments are not weak. Because the test statistic exceeds the critical value in Wald test, we reject the null hypothesis of weak instruments.

TABLE 3
Regression Results for Primary Specification

	Dependent Variable = Z-score							
	Net Premiums Written				Assets			
Variable	(1) OLS	(2) OLS	(3) 2SLS	(4) 2SLS	(5) OLS	(6) OLS	(7) 2SLS	(8) 2SLS
Concentration (HHI)	−0.707***		−0.894***		−0.411***		−0.722***	
	(0.171)		(0.225)		(0.100)		(0.183)	
Concentration (C4)		−0.457*		−2.457***		−0.493***		−0.929***
		(0.269)		(0.634)		(0.127)		(0.235)
FirmSize	0.169***	0.164***	0.143***	0.148***	0.169***	0.168***	0.144***	0.143***
	(0.029)	(0.029)	(0.030)	(0.031)	(0.029)	(0.029)	(0.031)	(0.031)
FirmSize^2	−0.004***	−0.004***	−0.002*	−0.003*	−0.004***	−0.004***	−0.003*	−0.003*
	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)	(0.001)
Catastrophes	−0.140**	−0.135**	−0.147**	−0.082	−0.190***	−0.187***	−0.272***	−0.268***
	(0.062)	(0.063)	(0.062)	(0.067)	(0.063)	(0.063)	(0.067)	(0.067)
Leverage	−0.317***	−0.316***	−0.320***	−0.318***	−0.318***	−0.318***	−0.321***	−0.322***
	(0.008)	(0.008)	(0.009)	(0.009)	(0.008)	(0.008)	(0.009)	(0.009)
ProdHHI	−0.239***	−0.247***	−0.262***	−0.264***	−0.238***	−0.239***	−0.264***	−0.265***
	(0.032)	(0.032)	(0.068)	(0.068)	(0.033)	(0.033)	(0.067)	(0.067)
GeoHHI	−0.047*	−0.047*	−0.131**	−0.129**	−0.048*	−0.047*	−0.132**	−0.132**
	(0.027)	(0.027)	(0.052)	(0.052)	(0.027)	(0.027)	(0.052)	(0.052)
HOLineShare	−0.172***	−0.181***	−0.126***	−0.128***	−0.171***	−0.172***	−0.130***	−0.131***
	(0.046)	(0.046)	(0.048)	(0.049)	(0.046)	(0.046)	(0.048)	(0.049)
InvestinBonds	0.066*	0.070**	0.146**	0.143**	0.066*	0.067*	0.143**	0.144**
	(0.035)	(0.035)	(0.067)	(0.068)	(0.035)	(0.035)	(0.067)	(0.067)
Reinsurance	−0.064***	−0.062***	−0.058***	−0.057***	−0.064***	−0.063***	−0.057***	−0.057***
	(0.020)	(0.020)	(0.019)	(0.020)	(0.020)	(0.019)	(0.020)	(0.020)
AssetGrowth	0.002	0.003	0.031	0.033	0.000	0.000	0.029	0.028
	(0.011)	(0.011)	(0.020)	(0.021)	(0.011)	(0.011)	(0.020)	(0.019)
Mutual	0.168***	0.172***	0.152***	0.153***	0.168***	0.168***	0.152***	0.152***
	(0.019)	(0.019)	(0.020)	(0.020)	(0.019)	(0.019)	(0.020)	(0.020)
Group	0.060**	0.066***	0.057**	0.056**	0.060**	0.061**	0.056**	0.057**
	(0.024)	(0.024)	(0.024)	(0.025)	(0.024)	(0.024)	(0.024)	(0.024)
Interest	0.126***	0.133***	0.150***	0.171***	0.142***	0.141***	0.188***	0.185***
	(0.022)	(0.023)	(0.022)	(0.022)	(0.023)	(0.023)	(0.024)	(0.023)
Constant	−0.496	1.365***	−0.977	−1.077	0.502	1.309***	−0.394	0.947***
	(0.615)	(0.386)	(0.810)	(0.853)	(0.389)	(0.231)	(0.669)	(0.350)
Hausman test (p-value)			0.034	0.000			0.009	0.004
Partial R^2			0.267	0.171			0.280	0.269
F-test (p-value)			0.000	0.000			0.000	0.000
Hansen's J-test (p-value)			0.279	0.262			0.276	0.275
Adjusted R^2	0.1880	0.1876	0.1733	0.1695	0.1880	0.1880	0.1714	0.1710
Observations	14,017	14,017	14,017	14,017	14,017	14,017	14,017	14,017

***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

Table 3 shows that the coefficients of market concentration measured by the industry HHI are statistically significant and negative across all models, indicating that market concentration is inversely associated with the insurer's financial stability. The results are consistent with the concentration-fragility view that less concentrated market structures with many firms, each with a small share of the market, are more financially stable than the concentrated market structures with a few large firms that supply most of the market. The significant and negative coefficients of the four-firm (C4) concentration ratios employed as an alternative measure of market concentration also support this view.

The results of explanatory variables in Table 3 are generally consistent with theoretical predictions. The coefficients of firm size and the square of firm size are statistically significant across all estimations, showing that nonlinear relationships exist between firm size and an insurer's insolvency risk. Specifically, the positive coefficients on firm size indicate that, on average, large insurers are likely to have greater financial stability than small insurers. This result is consistent with prior findings suggesting that large firms have lower insolvency risk and higher profitability than smaller firms (Cummins and Nini, 2002; Liebenberg and Sommer, 2008). However, the negative signs on the coefficients of the quadratic term imply that an increase in firm size beyond a certain threshold may have a diminishing effect on the insurer's financial stability. The coefficients of the exposure to catastrophes are negative and significant, indicating that severe natural disasters may deplete insurers' capital capacity and pose a significant financial impact on the U.S. property–liability insurance industry. Underwriting leverage is negatively and significantly related to financial stability at the 1 percent level across all models. The result implies that insurers may be at greater insolvency risk if they attempt to increase premium revenues without maintaining corresponding policyholders' surplus.

Diversification appears to have favorable effects on the insurer's financial stability. Both product diversification (ProdHHI) and geographical diversity (GeoHHI) are significantly and negatively related to financial stability in all estimations. The result implies that diversifying in different lines of business or operating in multiple states may reduce the volatility of underwriting returns and hence be more advantageous in improving financial stability than the product and geographical focus. The coefficients of the homeowners line share are negative and significant at the 1 percent level in all estimations, suggesting that firms with more exposure in the relatively dependent homeowners lines are more financially unstable. This finding might be better explained by the differences that commercial lines are more flexible in underwriting decisions, better geographically diversified on average, and have greater reinsurance coverage than homeowners lines (Born and Klimaszewski-Blettner, 2013).[15] In addition, more restrictive regulation in homeowners lines would deter an insurer's ability to recover financially following large losses. The coefficients of the proportion of invested assets in bonds are significant and positive, suggesting

[15] See Born and Klimaszewski-Blettner (2013) for more detailed discussions about significant differences in underwriting flexibility, regulation intensity, reinsurance structure, geographical diversification, and market concentration between homeowners and commercial lines.

that the higher the percentage of a firm's investment in less risky assets, the lower its chance of encountering financial instability. This finding is consistent with the observation of Elango, Ma, and Pope (2008) that the proportion of invested assets in stocks, real estate, and mortgages is negatively related to risk-adjusted performance. Contrary to expectations, the coefficients of reinsurance ratios are negative and significant in all estimations. The results indicate that firms with more reinsurance are not necessarily financially more stable. Garven and Lamm-Tennant (2003) suggest that highly leveraged firms utilize more reinsurance due to the greater risk of insolvency. Cole and McCullough (2006) provide evidence that less profitable firms demand more reinsurance, and potential financial distress increases the demand for reinsurance. These findings imply that primary insurers with higher reinsurance are more likely to have a constraint on their capacity for bearing additional risk and already show a high risk exposure. As documented by Cole and McCullough, it appears that primary insurers purchase more reinsurance in an effort to mitigate potential financial constraints. The coefficients of asset growth ratios are not significant.

The sign on Mutual is positive and significant, consistent with the argument that mutual insurers may have less incentive to increase asset risk relative to stock firms. The significant and positive coefficients of Group indicate that affiliated insurers within group are more financially stable than the unaffiliated single companies. The results in Table 3 show that macroeconomic factors certainly play an important role in the insurer's financial soundness. The coefficients of the interest rate changes are positive and significant, indicating that a decline in interest rates may have a negative impact on the insurer's financial stability. Insurers generally hold a large part of their investments in relatively safe interest rate instruments. Thus, decreases in interest rates represent a substantial reduction in investment income[16] and may also encourage the potential assumption of excessive risks, leading to further financial instability.

State-Level Sample Analysis

Competition in the market for property–liability insurance tends to be local, and insurance regulation and concentration ratios vary substantially by state. Under these circumstances, it might be more appropriate to analyze a state market as opposed to a national market. Prior studies that investigate the interdependence of market structure and performance in the insurance industry focus on the results by state (e.g., Choi and Weiss, 2005; Bajtelsmit and Bouzouita, 1998). Bajtelsmit and Bouzouita (1998) argue that the use of national-level premium data rather than state-level

[16] The primary income from insurers' investments consists of (1) net investment income (e.g., coupon payments on fixed income securities, dividend payments on equity holdings, income generated by real estate holdings) and (2) net realized investment gains or losses (investment gains or losses realized on the sale of investments). Bond prices and interest rates (or market yields) always move in opposite directions. When interest rates rise (fall), a bond's value declines (rises). Thus, interest rate changes have offsetting effects for (1) net investment income and (2) net realized investment gains or losses. Because the proportion of net investment income is greater than that of realized capital gains/losses on average, insurers' overall investment income is likely to be adversely impacted by low interest rates.

premium data is likely to disguise the concentration that exists in local markets. In this section, we reexamine the relationship between market concentration and financial stability using company data by state. To test our main hypotheses, the following equation is estimated:[17]

$$\begin{aligned} \text{SD\_LR}_{i,s,t} \text{ or } \text{SD\_CR}_{i,s,t} = {} & \alpha_0 + \alpha_1 \text{St.Concentration}_{s,t} + \alpha_2 \text{St.FirmSize}_{i,s,t} \\ & + \alpha_3 \text{St.FirmSize}^2_{i,s,t} + \alpha_4 \text{St.Catastrophes}_{s,t} \\ & + \alpha_5 \text{Leverage}_{i,t} + \alpha_6 \text{St.HOLineShare}_{i,s,t} \\ & + \alpha_7 \text{Reinsurance}_{i,t} + \alpha_8 \text{AssetGrowth}_{i,t} + \alpha_9 \text{Mutual}_{i,t} \\ & + \alpha_{10} \text{Group}_{i,t} + \alpha_{11} \text{Regulation}_{s,t} + \alpha_{12-25} \text{Year}_{i,t} + \mu_{i,s,t}, \quad (4) \end{aligned}$$

where i represents the group or unaffiliated company, s refers to state, t is time, and $\mu_{i,s,t}$ is the error term.[18] $\text{SD\_LR}_{i,s,t}$ ($\text{SD\_CR}_{i,s,t}$) is the standard deviation of state-wide loss ratio (combined ratio). $\text{St.Concentration}_{s,t}$ is the Herfindahl concentration index by state.[19] As an alternative measure of state-level market concentration, we also employ state-wide 4-, 8-, and 20-firm concentration ratios (C4, C8, and C20) calculated as the proportion of direct premiums written held by the largest 4, 8, and 20 insurers, respectively, in each state. $\text{St.FirmSize}_{i,s,t}$ is measured by the natural logarithm of direct premiums written of each insurer for each state. Similar to Equation (3), we include the square of firm size ($\text{St.FirmSize}^2_{i,s,t}$) to examine the nonlinear relationships between firm size and its financial stability. $\text{St.Catastrophes}_{s,t}$ is calculated as the state-wide sum of property damages from natural catastrophes divided by the sum of all insurers' direct premiums written in fire, allied, commercial multiple peril, and homeowners lines in that state. $\text{St.HOLineShare}_{i,s,t}$ is measured by the percentage of an insurer's direct premium written in homeowners line for each state. $\text{Leverage}_{i,t}$, $\text{Reinsurance}_{i,t}$, $\text{Asset Growth}_{i,t}$, $\text{Mutual}_{i,t}$, and $\text{Group}_{i,t}$ are the same variables used in Equation (3). We also include an indicator variable, $\text{Regulation}_{s,t}$ which is equal to one if the state is rate regulated, and zero otherwise.[20] We expect a negative sign on this variable if insurance price regulation has had a significant impact on stabilizing rate levels and claims costs over time. Finally, $\text{Year}_{i,t}$ is year dummies. The definitions and expected signs of the variables in Equation (4) are presented in Table 2.

Because the Z-score cannot be measured directly by state and it is not easy to allocate investment income by state,[21] we choose the standard deviation of statewide loss ratio

[17] Similar to Choi and Weiss (2005), we do not include state dummies in this equation where we control for insurance price regulation, which varies by state.

[18] For brevity, St. is used to indicate the state-level measurement.

[19] The state Herfindahl concentration index is calculated by the sum of squared market share of direct premiums written for each insurer in the state.

[20] Following Harrington (2002) and Grace and Phillips (2008), we classify any state that has state-made rates, a prior approval law without a deemer provision, or a prior approval law with a deemer provision as a rate-regulated state.

[21] The information on the components of the Z-score (return on assets, capital-to-asset ratio, and the volatility of ROA) is not available by state, and thus the state-level Z-score cannot be constructed due to data limitations.

and combined ratio as alternative measures of an insurer's financial stability.[22] The combined ratio is the most common measure of underwriting profitability and calculated by the sum of the loss ratio and the expense ratio. The loss ratio is the ratio of losses incurred and loss adjustment expenses to premiums earned and the expense ratio is measured as the insurer's underwriting expenses divided by written premiums. A high combined ratio indicates adverse underwriting results. The standard deviation of loss ratio and combined ratio is calculated by using 5-year rolling-periods data. We use company-wide loss and combined ratios, not by those on the basis of individual line of business, because potential cross-subsidization across lines of business may affect the results (Choi and Weiss, 2005).

If market concentration and financial stability are endogenously determined as discussed in the "Primary Specification" section, the OLS estimator will lead to bias. We employ the 2SLS approach to mitigate endogeneity concerns. In this state market analysis, we initially choose 5-year average growth rate of an insurer's state-level direct premiums written, state-wide average firm size (measured by the natural logarithm of direct premiums written of each insurer for each state) for the prior 5 years, number of firms operating in each state, 3-year average growth rate of state-level real GDP, and lagged values of firm characteristics included in Equation (4) as potential instruments for market concentration variables. Following the procedures described in the "Primary Specification" section, we conduct several tests including the *F*-test and Hansen's *J*-test to select appropriate instruments. Similar to the previous results, both the 5-year average growth rate of an insurer's state level direct premiums written and the 3-year average growth rate of state-level real GDP meet the relevance and validity conditions.

We present the estimation results of Equation (4) using OLS methods and 2SLS techniques in Table 4.[23] Table 4 shows the results using the state Herfindahl concentration index and four-firm concentration ratio.[24] The first (last) four columns use the standard deviation of statewide loss ratio (combined ratio) to measure an insurer's financial stability. Standard errors that adjust for heteroskedasticity and firm-level clustering are reported in parentheses. The *p*-values of the Hausman test of endogeneity in the 2SLS estimations indicate that the market concentration variables are not exogenous, consistent with the findings of the "Primary Specification" section. It appears that instruments account for 20–22 percent of the variation of market concentration in the first stage as demonstrated by the partial R^2 of excluded instruments. The *F*-tests reject the null hypothesis of weak instruments at the 1 percent significance level. In addition, the *p*-values of Hansen's *J*-test support the hypothesis that the instruments are valid.

[22] Ho, Lai, and Lee (2013) use the standard deviation of a company's loss ratio to measure an insurer's underwriting risk. They use 5-year rolling-periods data to calculate standard deviation of loss ratios, standard deviation of return on assets, and standard deviation of return on investment.

[23] The variance inflation factor (VIF) is estimated to examine the presence of multicollinearity among the variables used in the regressions. Values of VIF less than 2.0 for all variables indicate that there is no multicollinearity problem in our models.

[24] The results using 8- and 20-firm concentration ratios are available from the authors upon request.

TABLE 4
Regression Results for State-Level Sample

	Dependent Variable = SD of Loss Ratio				Dependent Variable = SD of Combined Ratio			
Variable	(1) OLS	(2) OLS	(3) 2SLS	(4) 2SLS	(5) OLS	(6) OLS	(7) 2SLS	(8) 2SLS
St.Concentration (HHI)	0.077***		0.771**		0.075***		0.787**	
	(0.023)		(0.316)		(0.023)		(0.327)	
St.Concentration (C4)		0.050*		0.934**		0.050*		0.952**
		(0.030)		(0.392)		(0.029)		(0.404)
St.FirmSize	−0.458***	−0.459***	−0.444***	−0.445***	−0.585***	−0.584***	−0.571***	−0.573***
	(0.017)	(0.017)	(0.073)	(0.073)	(0.016)	(0.016)	(0.068)	(0.069)
St.FirmSize^2	0.021***	0.021***	0.020**	0.020**	0.033***	0.033***	0.032***	0.032***
	(0.002)	(0.002)	(0.008)	(0.008)	(0.002)	(0.002)	(0.007)	(0.007)
St.Catastrophes	0.066***	0.066***	0.066***	0.067***	0.065***	0.066***	0.065***	0.066***
	(0.003)	(0.003)	(0.004)	(0.004)	(0.003)	(0.003)	(0.004)	(0.004)
Leverage	−0.032	−0.032	−0.026	−0.026	−0.022	−0.022	−0.018	−0.018
	(0.030)	(0.030)	(0.030)	(0.030)	(0.024)	(0.024)	(0.024)	(0.024)
St.HOLineShare	0.008	0.008	0.009	0.009	0.009	0.009	0.008	0.008
	(0.017)	(0.016)	(0.017)	(0.017)	(0.030)	(0.030)	(0.029)	(0.029)
Reinsurance	0.788***	0.787***	0.793***	0.782***	0.909***	0.901***	0.911***	0.900***
	(0.028)	(0.028)	(0.248)	(0.247)	(0.028)	(0.027)	(0.207)	(0.206)
AssetGrowth	0.100***	0.099***	0.110***	0.107***	0.118***	0.117***	0.128***	0.125***
	(0.007)	(0.007)	(0.014)	(0.014)	(0.007)	(0.007)	(0.013)	(0.013)
Mutual	−0.100***	−0.101***	−0.084	−0.086	−0.115***	−0.116***	−0.099	−0.101
	(0.009)	(0.009)	(0.064)	(0.064)	(0.009)	(0.009)	(0.063)	(0.063)
Group	0.111***	0.112***	0.091	0.100	0.149***	0.150***	0.128*	0.137*
	(0.013)	(0.013)	(0.079)	(0.079)	(0.013)	(0.013)	(0.073)	(0.074)
Regulation	0.028***	0.032***	0.022	0.030**	0.030***	0.035***	0.032**	0.035***
	(0.005)	(0.005)	(0.015)	(0.012)	(0.005)	(0.005)	(0.014)	(0.010)
Constant	−0.024	−0.211***	2.099**	0.731*	0.246***	0.072	2.430**	1.030**
	(0.080)	(0.050)	(0.959)	(0.437)	(0.079)	(0.049)	(0.999)	(0.449)
Hausman test (p-value)			0.000	0.000			0.000	0.000
Partial R^2			0.198	0.219			0.199	0.220
F-test (p-value)			0.000	0.000			0.000	0.000
Hansen's J-test (p-value)			0.279	0.448			0.217	0.182
Adjusted R^2	0.1766	0.1764	0.1566	0.1573	0.2102	0.2097	0.1894	0.1904
Observations	160,134	160,134	160,134	160,134	160,134	160,134	160,134	160,134

***,**, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

As shown in Table 4, the coefficients of the Herfindahl concentration index and four- firm concentration ratios are positive and significant in all models, indicating that the volatility of an insurer's underwriting returns is high in more concentrated states than in less concentrated states. The results provide support for the concentration-fragility view that insurers operating in highly concentrated markets (states) are likely to be financially less stable than those in less concentrated markets (states).

The results of control variables in Table 4 are largely consistent with our prior expectations. The negative (positive) and significant coefficients on the statewide firm

size (the square of firm size) indicate that the relationships between firm size and its financial stability are nonlinear, consistent with our previous findings in the "Primary Specification" section. The coefficients of the catastrophes are positive and significant at the 1 percent level in all estimations, showing that severe damages from natural catastrophes are directly and positively related to the volatility of an insurer's underwriting earnings. The reinsurance ratios and group are significantly and positively related to the standard deviation of state-wide loss ratios and combined ratios. The results suggest that the increase in reinsurance ratios and member of group do not necessarily help insurers improve their financial stability. The coefficients of asset growth are significantly positive at the 1 percent level in all models, consistent with the general view that rapid asset growth is not taken as a positive signal of financial health of the insurers. In addition, fast asset growth is likely to influence the insurer's financial stability negatively if asset growth results from lax underwriting policy or inadequate pricing where an insurer grows its book of business by charging less than market rates. Interestingly, the coefficients of regulation are significant and positive in seven of the eight models, indicating that insurance price regulation does not have a positive effect on the insurer's financial stability. It appears that the legal authority for an insurance regulator to oversee prices may not function well in reducing the uncertainty associated with the insurer's loss potential. On the other hand, the results in Table 4 show that the underwriting leverage and homeowners line share have no effect on the insurer's financial stability when using state-level data. The organizational form seems not strongly relevant to the volatility of state-level underwriting returns since it is insignificant in 2SLS methods.

Robustness Tests

We perform robustness tests by using alternative measures of an insurer's financial stability. To potentially represent the category of an insurer's asset risk, we consider a volatility-of-returns-based measure called opportunity asset risk (OAR) following Baranoff, Papadopoulos, and Sager (2007) and Eling and Marek (2013). The OAR is measured by the standard deviation of the weighted average returns of an insurer's invested asset portfolio. We classify an insurer's invested assets into six categories: stocks, government bonds, corporate bonds, real estate, mortgages, cash, and other invested assets. Because an insurer's investment returns are not available in sufficient frequency, we need to calculate the hypothetical returns that the insurer could have earned by investing its portfolio components in related investment indices. The monthly standard rate of return series are used for the calculation of an insurer's asset portfolio returns.[25]

To calculate the weighted average returns of an insurer's invested asset portfolio, an individual company's asset allocation mix (the percentage of each invested asset) is

[25] Similar to Cummins, Lin, and Phillips (2005) and Shim (2010), the monthly estimates of asset portfolio returns are obtained as follows: stocks—the total return on the Standard & Poor's 500 stock index; government bonds—the Ibbotson intermediate term total return; corporate bonds—Moody's corporate bond total return; real estate—the National Association of Real Estate Investment Trusts (NAREIT) total return; mortgages—the Bank of America Merrill Lynch mortgage-backed securities total return; and cash and other invested assets—the 30-day U.S. Treasury bill rate.

multiplied by corresponding monthly standard rate of return series. Using monthly standard rate of return series of six asset categories and individual firm's asset weights, we calculate 12 monthly portfolio returns for each year for each insurer.[26] The resultant 12 weighted average returns are used to compute the annualized standard deviation of the portfolio returns, which represents an insurer's asset risk. In this case, the difference of asset risk among firms is determined by the individual company's choice of asset allocation because all firms are presumed to produce the equivalent monthly return for each category of assets.

As an alternative measure of a firm's financial stability, we also choose A.M. Best's financial strength ratings, which measure an insurer's ability to meet its financial obligations based on firm's balance sheet strength, operating performance, and business profile. To examine the relationship between market concentration and an insurer's financial strength using A.M. Best's ratings, we conduct a probit analysis where the dependent variable is equal to one for firms with A.M. Best's ratings of A++ or A+, and zero otherwise. The maximum likelihood estimator is used for the probit analysis. To address the potential endogeneity problem, we also perform a two-stage IV probit regression analysis with the same instruments used in the previous 2SLS methods of Table 3.

The results using the OAR and A.M. Best's ratings as dependent variables are presented in Tables 5 and 6, respectively. Panel A in Table 5 (6) shows the results of OLS (probit) regression, while Panel B in Table 5 (6) presents the estimation of 2SLS (two-stage IV probit) regression. We add 8- and 20-firm concentration ratios (C8 and C20) to examine the sensitivity of our results to changes in the measurement of market concentration. Although all other control variables used in Table 3 are included in the regressions, Tables 5 and 6 present only the results of our key independent variables to conserve space. As shown in Table 5, the coefficients of all market concentration variables (except for the four-firm concentration ratio measured by using net premiums written) are positive and significant, indicating that insurers in highly concentrated markets are likely to be exposed to high asset risks by investing more in volatile assets. High volatility in an insurer's invested asset portfolio may lead to overall financial instability. Likewise, the coefficients of market concentration variables in Table 6 are significant and negative, suggesting that an increase in market concentration is less likely to have a positive effect on the probability that an insurer will have superior financial strength ratings. These results confirm that our key findings in Table 3 are unaffected by alternative measures of an insurer's financial stability and market concentration.

In analyses available upon request, we conduct additional tests by using the Newey and West (1987) variance estimator, which produces consistent estimates in the presence of possible heteroskedasticity and serial correlation.[27] We repeat all

[26] Note that return series vary by month, but individual firm's asset weights change by year due to their availability only once a year.

[27] We also estimate a model based on the first-differencing for all variables that change over time. As a further check to ensure that the likely endogeneity of market concentration variables are not biasing the results, we estimate Equation (3) using the two-step generalized method of moments (GMM) procedure of Arellano and Bond (1991). The results are available from the authors upon request.

TABLE 5
Regression Results for Opportunity Asset Risk: OLS and 2SLS

	Dependent Variable = Opportunity Asset Risk							
	Net Premiums Written				Assets			
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: OLS Results for the Effect of Market Concentration on Opportunity Asset Risk (OAR)								
Concentration (HHI)	0.011***				0.010***			
	(0.002)				(0.001)			
Concentration (C4)		0.001				0.012***		
		(0.003)				(0.002)		
Concentration (C8)			0.006***				0.017***	
			(0.001)				(0.002)	
Concentration (C20)				0.011***				0.021***
				(0.002)				(0.003)
Adjusted R^2	0.2369	0.2338	0.2356	0.2368	0.2398	0.2383	0.2391	0.2387
Observations	14,017	14,017	14,017	14,017	14,017	14,017	14,017	14,017
Panel B: 2SLS Results for the Effect of Market Concentration on Opportunity Asset Risk (OAR)								
Concentration (HHI)	0.007***				0.010***			
	(0.002)				(0.003)			
Concentration (C4)		0.008***				0.013***		
		(0.003)				(0.004)		
Concentration (C8)			0.005***				0.010***	
			(0.002)				(0.003)	
Concentration (C20)				0.006***				0.009***
				(0.002)				(0.003)
Adjusted R^2	0.2377	0.2340	0.2366	0.2375	0.2414	0.2398	0.2397	0.2384
Observations	14,017	14,017	14,017	14,017	14,017	14,017	14,017	14,017

***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

TABLE 6
Regression Results for A.M. Best's Ratings: Probit and Two-Stage IV Probit

	Dependent Variable = A.M. Best's Ratings							
	Net Premiums Written				Assets			
Variable	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Panel A: Probit Regression Results for the Effect of Market Concentration on A.M. Best's Ratings								
Concentration (HHI)	−1.952***				−1.112***			
	(0.487)				(0.308)			
Concentration (C4)		−1.111				−1.385***		
		(0.836)				(0.386)		
Concentration (C8)			−1.511***				−1.963***	
			(0.396)				(0.535)	
Concentration (C20)				−1.758***				−2.386***
				(0.550)				(0.847)
Log-likelihood	−1,384	−1,392	−1,385	−1,387	−1,386	−1,386	−1,386	−1,389
Pseudo R^2	0.4378	0.4350	0.4375	0.4366	0.4372	0.4372	0.4373	0.4362
Observations	14,017	14,017	14,017	14,017	14,017	14,017	14,017	14,017
Panel B: Two-stage IV Probit Regression Results for the Effect of Market Concentration on A.M. Best's Ratings								
Concentration (HHI)	−2.917***				−2.351***			
	(0.691)				(0.549)			
Concentration (C4)		−7.835***				−3.016***		
		(1.820)				(0.703)		
Concentration (C8)			−2.224***				−4.037***	
			(0.528)				(0.944)	
Concentration (C20)				−3.312***				−5.785***
				(0.790)				(1.373)
Log-likelihood	18,600	21,988	16,969	19,749	11,707	14,198	17,991	23,450
Wald test of exogeneity (p-value)	0.0002	0.0000	0.0000	0.0000	0.0004	0.0005	0.0004	0.0000
Observations	14,017	14,017	14,017	14,017	14,017	14,017	14,017	14,017

***, **, and * indicate significance at the 1, 5, and 10 percent levels, respectively.

regressions using the standard deviation of loss ratio and combined ratio calculated on the basis of 10-year rolling-periods data as dependent variables. The estimations suggest that primary results are robust to alternative methodologies and variations in the model's specification. In particular, the signs of the coefficients on the market concentration are unaffected and remain statistically significant in all variants, strengthening the conclusion of a negative impact of market concentration on insurers' financial stability.

CONCLUSION

The issue of whether concentrated markets are financially more (or less) stable than less concentrated markets is important to regulators who are concerned about insurers' ability to meet their financial obligations to policyholders. This study explores the relationship between market concentration and financial stability using

the sample of U.S. property–liability insurance industry over the period 1992–2010. We measure the insurer's financial stability with an accounting measure of insolvency risk, the *Z*-score. In the state-level market analysis, we use the standard deviation of statewide loss ratio and combined ratio as alternative measures of an insurer's financial stability. The industry- and state-level HHI and 4-, 8-, and 20-firm concentration ratios (C4, C8, and C20) for NPW and assets are used to measure market concentration. We employ the 2SLS estimation method along with instrumental variables to deal with potential endogeneity problems.

The results of empirical tests show that the impact of market concentration is significant on the insurer's financial stability. We find evidence supporting the concentration-fragility view when using industry-level market concentration, indicating that higher national insurance market concentration is associated with lower financial stability of U.S. property–liability insurance companies. The results using state-level market concentration also support the concentration-fragility view. The article's results hold when applying a variety of further estimation methods and employing alternative measures of an insurer's financial stability such as opportunity asset risk and A.M. Best's ratings. Our results are consistent with several theoretical and empirical banking studies (e.g., Chong, 1991; Caminal and Matutes, 2002; De Nicoló, Bartholomew, Zaman, and Zephirin, 2004; Uhde and Heimeshoff, 2009). The outcomes of this research suggest that regulators should be more concerned about increasingly concentrated market structure where a few very large firms dominate market share rather than the competitive market structure with many firms, each with a small share of the market, because the risk of firm failures would be more pronounced in a concentrated market.

Empirical results show other important determinants in ensuring a safe and sound insurance system. Among them, large insurers are likely to be financially more stable than small insurers. However, the nonlinear relationships between firm size and its insolvency risk imply that an extreme increase in firm size may have a negative influence on the insurer's financial stability. We provide evidence that the increase in natural catastrophes undermines the insurer's financial strength. The inverse relationship between leverage and the *Z*-score suggests that higher premium growth without corresponding policyholders' surplus may harm the insurer's financial stability. Both product and geographical diversification appear to have a positive impact on the insurer's financial strength. Mutual insurers tend to have lower probability of insolvency relative to stock firms. We find that interest rate changes are positively associated with the insurer's financial strength. By identifying the firm-specific factors along with market structure and macroeconomic status that affect insurers' financial stability, our results should offer regulators and industry practitioners important implications about the determinants of the firm's financial health.

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